general-coverage receiver

part 2 (final): construction and operation

Since publishing the first instalment of this article, considerable interest has been expressed in the design by many of our readers. As always, however, the proof of the pudding is in the eating, and actually building the receiver is no mean job. Fortunately, ready-made PCBs are available, and the receiver is easy-going on adjustment.

Design by G. Baars, PE1GIC

Before discussing the construction of the general-coverage receiver, we think it is fair to warn that the project should not be attempted by beginners without any experience in building RF circuits. But that is not to say you may not try, assuming that you have considered the following conditions:

- ❍ you can rely on a more experienced 'ham' to help you;
- ❍ you are capable of working very accurately;
- ❍ you are not under the stress of meeting deadlines, say, for completing a school project or GCSE assignment;
- ❍ a set of plastic coil adjustment tools is available;
- ❍ you are willing and able to obtain all the parts as specified, preferably from a reputed kit supplier.

In the following discussions it is assumed that the constructor has reasonable experience in building RF circuits printed-circuit boards. Also, for terms and abbreviations used here, you may have to refer back to part 1 of this article.

MAIN RECEIVER BOARD

The design of the main receiver board is shown in **Figure 4**. This is a pretty large board containing many discrete components. It is **double-sided, through-plated** and available ready-made from the Publishers (or through a kit supplier).

As you will not have failed to notice, the top side of the board acts as a ground plane which serves to keep RF interference (both radiated and picked-up) to a minimum.

Start by mounting the lower-profile parts on the board. As usual, check the value and, if necessary, orientation of each component before you mount it. For a change, the low profile parts include the following ICs: IC1 (TCA440), IC5 (MC145156), IC3 (MC3317), and IC4 (MB501L). These ICs are not mounted in sockets to ensure minimum stray capacitance and inductance around their pins.

Some components whose mounting

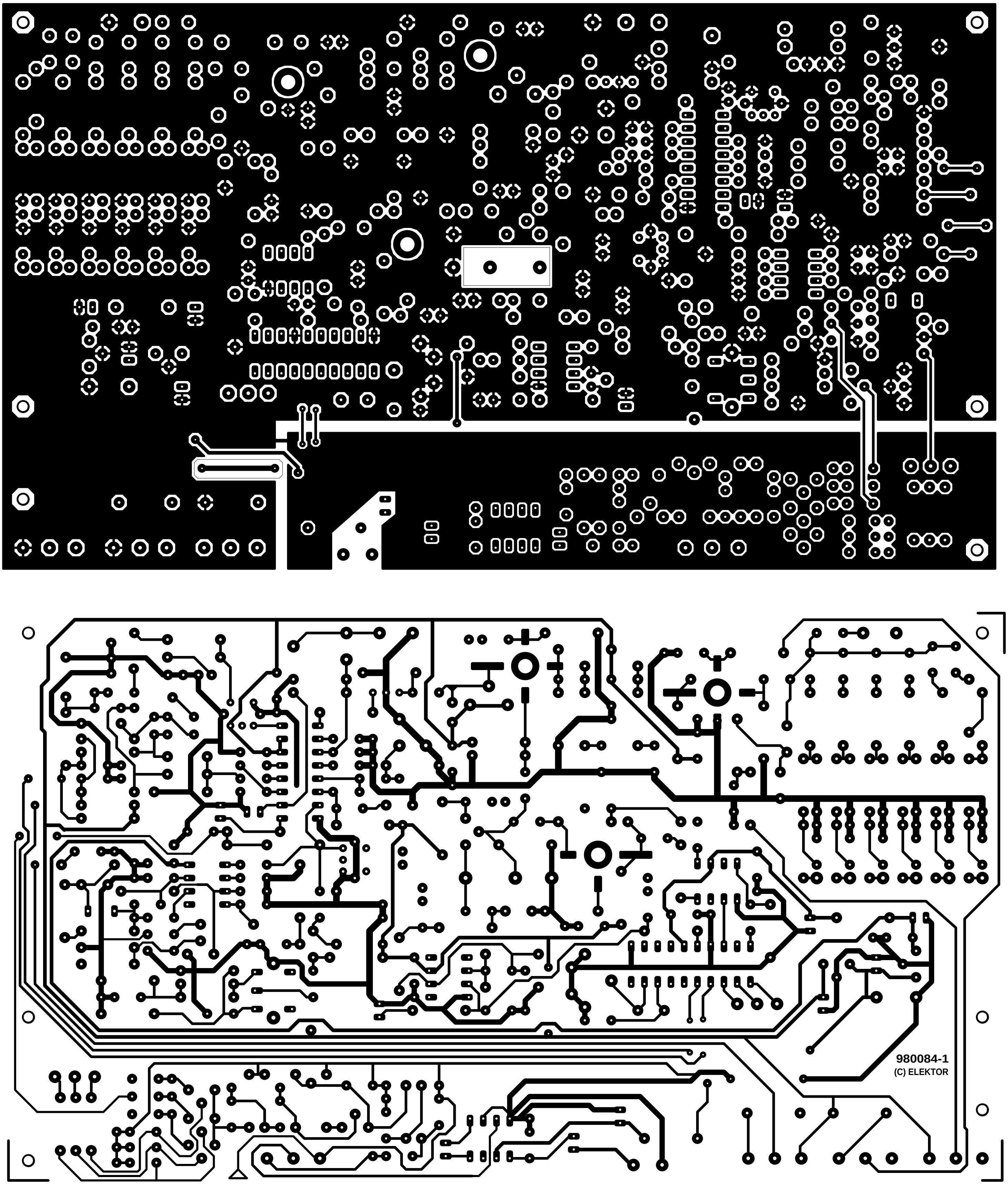
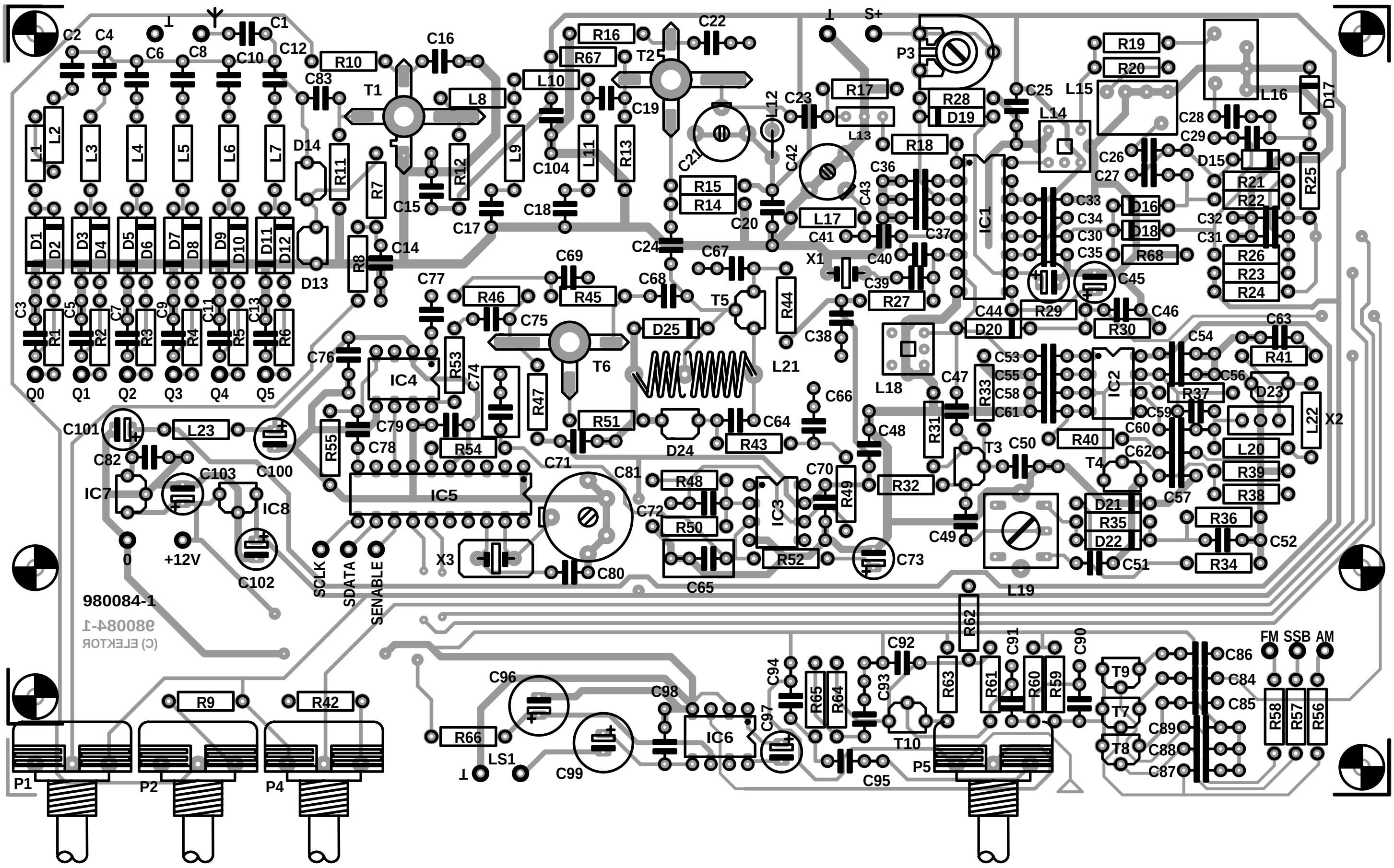


Figure 4. main receiver board layout (solder side and top side). The ready-made board supplied by the Publishers is through-plated.

deserves special attention will be discussed below.

Inductor L21

This consists of 7 turns of 0.5-mm dia (SWG26) silver-plated wire. The internal diameter is 6 mm, so the inductor is easily would on a 5-mm drill bit. Stretch the turns evenly to make the coil ends reach the holes in the PCB. Then determine the position of the tap, which should be connected at about 3 turns from the cold end. A very short piece of wire installed using tweezers will do the job. A small piece of foam plastic or similar may be pushed into the coil to reduce microphonic noises due to vibration.



COMPONENTS LIST

Main receiver board

Resistors:
R1-R6 = 330Ω
R7 = 1MΩ
R8,R9 = 100kΩ
R10,R41 = 330kΩ
R11,R14,R45,R52 = 33kΩ
R12 = 680Ω
R13,R40,R46 = 15kΩ
R15 = 68kΩ
R16 = 180Ω
R17,R68 = 3kΩ3
R18,R63 = 1kΩ
R19,R20,R32,R33,R55 = 2kΩ2
R21,R22,R25,R26,R59 = 10kΩ
R23,R24,R27 = 5kΩ6
R28 = 8kΩ2
R29 = 39kΩ
R30,R49,R64 = 12kΩ
R31 = 220kΩ
R34,R35,R54 = 82kΩ
R36,R43,R48,R50,R56,R57,R58,R60,R65,R67 = 47kΩ
R37,R38,R39,R42 = 22kΩ
R44 = 270Ω
R47 = 560Ω
R51 = 56Ω
R53 = 47Ω
R61 = 560kΩ
R62 = 3kΩ9
R66 = 1Ω
P1,P2,P4 = 50kΩ linear potentiometer, spindle dia. 4mm
P5 = 50kΩ logarithmic potentiometer, spindle dia. 4mm
P3 = 10kΩ preset H

Capacitors:
C1 = 6pF8
C2,C4,C6,C8,C10,C12,C26-C30,C50,C60,C69,C72,C92,C95 = 10nF
C3,C5,C7,C9,C11,C13-C16,C20,C22,C25,C31-C38,C43,C48,C54,C55,C57,C58,,C63,C66,C67,C70,C71,C76,C79,C82,C84-C89,C98,C104 = 100nF Sibatit (Siemens) or miniature ceramic
C17,C18,C53 = 10pF
C19,C83 = 220pF
C21,C42 = 22pF trimmer
C23 = 15pF
C24 = 56pF
C39,C41,C56,C75,C77,C78,C94 = 1nF
C40 = 4pF7
C44 = 4µF7 16V radial
C45 = 2µF2 16V radial
C46,C62 = 3nF3
C47 = 47pF
C49,C51,C80 = 100pF
C52 = 2nF2
C59 = 470pF
C61,C90 = 22nF
C64 = 150pF
C65,C74 = 220nF
C68 = 5pF6
C73 = 1µF 16V radial
C81 = 40pF trimmer
C91 = 4nF7
C93 = 3nF9
C96,C99 = 220µF 16V radial
C97 = 1µF5 16V radial
C100-C103 = 10µF 63V radial

Inductors:
L1,L2 = 1mH5
L3 = 0mH82
L4 = 120µH
L5 = 18µH
L6 = 3µH3
L7 = 0µH68
L8,L10 = 4µH7
L9 = 0µH33
L11 = 0µH22
L12,L17 = 0µH56
L13 = 45M15AU (Murata)
L14,L18 = LMC4101 (Toko)
L15 = SFR455J (Murata)
L16 = A55GGP (Toko) (12kHz)
L19 = YMCS17105R2 (Toko)
L20,L22 = 1 mH
L21 = 7 turns of 0.5mm dia (SWG26) silver-plated wire, internal dia. 6mm, tap at 3 turns from cold end.
L23 = 100µH

Semiconductors:
D1-D12 = BA479S
D13,D14 = BB112
D15-D18 = BA182
D19-D22 = BAT85
D23,D24 = BB509
D25 = BAT82
T1,T2 = BF961
T3,T5 = BF245C
T4,T7,T8,T9 = BS170
T6 = BFR91
T10 = BC549C
IC1 = TCA440 *
IC2 = NE612AN
IC3 = MC33171P * (Motorola)
IC4 = MB501-L * (Fujitsu)

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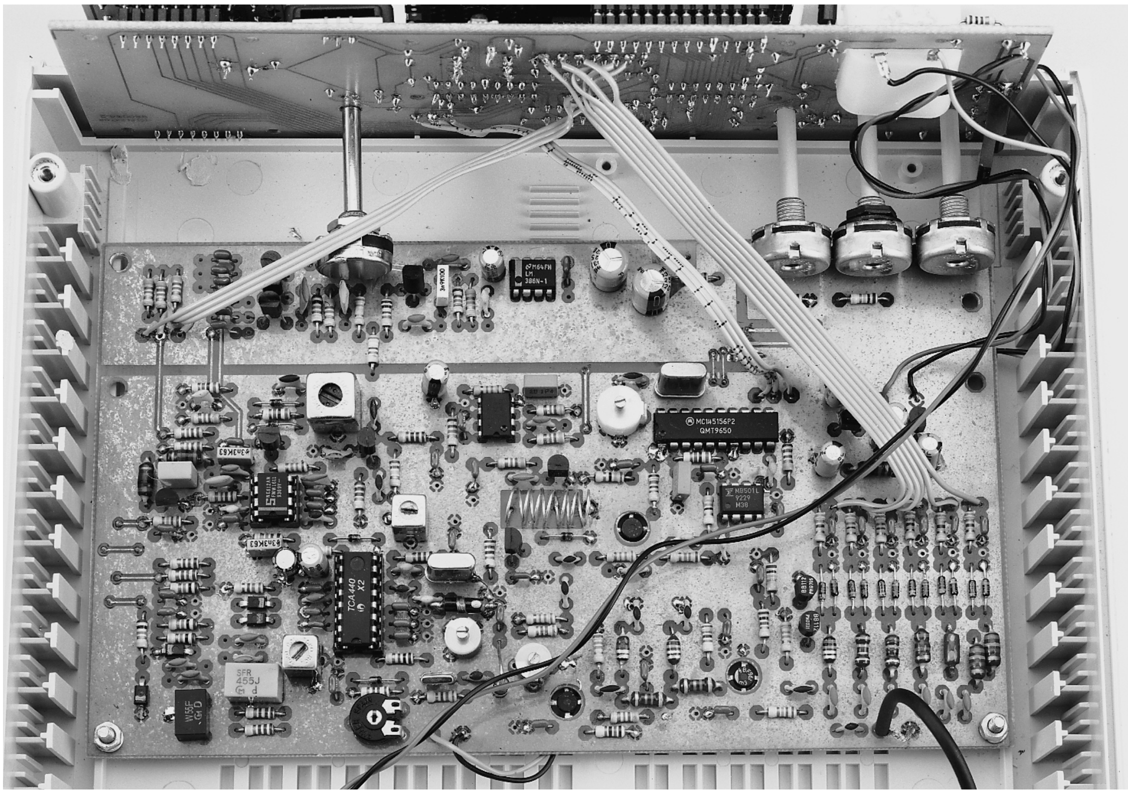

Figure 5. Top view of receiver board, provisionally mounted.

IC5 = MC145156-2 * (Motorola)
IC6 = LM386N-3
IC7 = 78L05
IC8 = 78L09

Miscellaneous:
M1 = moving coil meter, 'S' meter type, fsd 0.1-1.5mA
Ls1 = 8 ohms, 1 watt
X1 = 44.545MHz crystal, HC49U case, third overtone, 20pF loading
X2 = CSB455A resonator
X3 = 1MHz crystal, HC49U
Case: Bopla laboratory instrument case, size approx. 223mm (w) x 72mm (h) x 199mm (d), Conrad Electronics order no. 52 33 48-55
Aluminium front and rear panel, order code 52 33 56-55 (2 off)

* do not use an IC socket

For availability of special RF components used in this project we recommend contacting these suppliers
Cirkit Distribution Ltd (01992) 441306
Mainline Electronics (0116) 247 7551
BEC Component Distribution Ltd (01753) 549502
The prototype was built with components supplied by
Barend Hendriksen HF Elektronika BV, P.O. Box 66, NL-6970-AB Brummen, The Netherlands. Tel. (+31) 575 561866, fax (+31) 575 565012, email barendh@xs4all.nl

DG MOSFETs and BFR91
The two dual-gate MOSFETs in the circuit, T1, T2, are mounted at the underside of the board. Make sure they are fitted the right way around — the component overlay shows their (different!) orientations. The BF9xx series MOSFETs as supplied these days is no more sensitive to static discharges (ESD) than any common-or-garden CMOS IC, so no special precautions are required in this respect. Unusual as it may be that the type print on a particular MOSFET happens to be illegible from the top side, it is irrelevant! In other words: stick to the component orientation as indicated. In case of doubt refer back the circuit diagram, Figure 2 in part 1.

The BFR91 bipolar transistor is also mounted at the underside of the board. The longest terminal is the collector.

Trimmers
The terminals of the three trimmer capacitors on the board should be soldered as quickly as possible to prevent the heat of the solder bit deforming the plate structure and the internal PTFE material. Note that one trimmer, C21, is at the positive supply voltage. Set all three trimmers to mid-capacitance.

Preselector
No special precautions here, but do make sure you do know the value of each and every miniature choke before you fit it. Also, the PIN diodes must be fitted the right way around!

Quartz crystals
Connect the two quartz crystal cases to the ground plane by means of a short wires.

Toko inductors
These having two pins at one side and three at the other, they can not be mounted the wrong way around. The lugs at the can sides should also be soldered.

Potentiometers
Note that these are small types with a 4-mm spindle. Do not cut the spindles as yet, their lengths have to be determined accurately later.

RF input
Connect a short length of thin (3-mm dia.) coax cable (like RG174/U) to the RF input.

45M15AU first-IF filter
This metal-encapsulated component has three wires, the centre one being grounded. It can be mounted either way around.

You will notice that the board allows both 5 and 7.5-mm pitch 100-nF ceramic capacitors to be mounted (most are for decoupling). If you can not get hold of the 'Sibatit' capacitors we used in the prototype, they may be replaced with miniature ceramic ones.

Take your time to populate the main receiver board — many mistakes are made as a result of hurrying. **Figure 5** shows one of early prototypes of the receiver board, photographed from above.

CONTROL BOARD

This being a fairly traditional micro-

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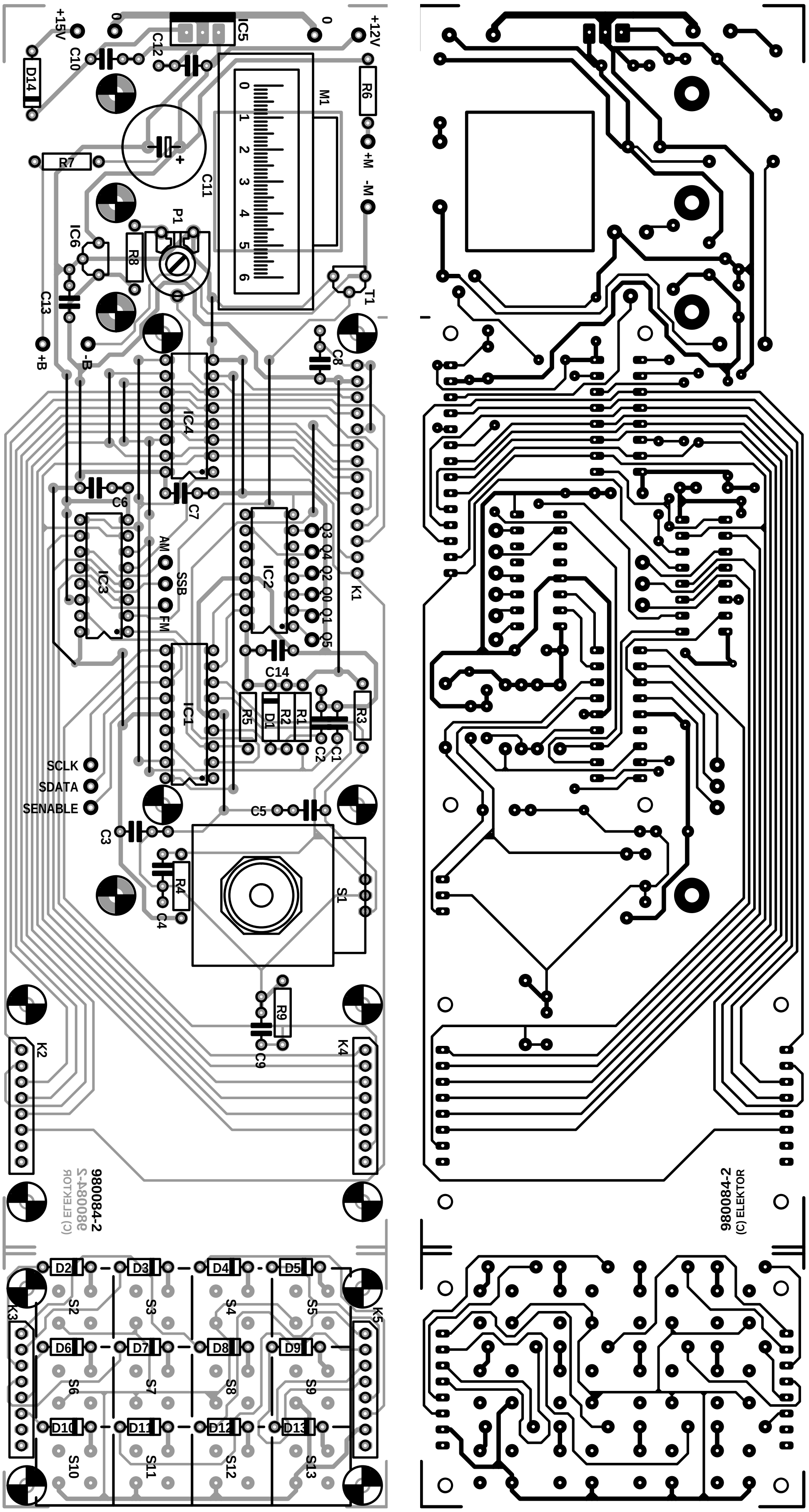

Figure 6. Copper track layout and component mounting plan of the control board. Unlike the main receiver board, this one is single-sided. Cut off the keyboard section.

COMPONENTS LIST
Control board

Resistors:
R1 = 4kΩ7
R2,R3,R4 = 15kΩ
R5,R9 = 10kΩ
R6 = 100Ω 0.5W
R7 = 150Ω
R8 = 22kΩ
P1 = 10kΩ preset H

Capacitors:
C1 = 27pF
C2-C8,C10,C12,C13,C14 = 100nF
C9 = 100pF
C11 = 470µF 25V radial

Semiconductors:
D1-D13 = 1N4148
D14 = 1N4001
T1 = BS170
IC1 = PIC16F84-04/P (order code 986517-1)
IC2 = 74HCT4017
IC3,IC4 = 4015
IC5 = 7812
IC6 = 78L05

Miscellaneous:
K1 = 14-way SIL socket
K2, K4 = 8-way SIL socket
K3, K5 = 8-way SIL pinheader
S1 = ECW1J-B24-AC0024 (Burr Brown) (supplier: Eurodis)
S2-S13 = pushbutton, 1 make contact, type D6-R-RD, plus cap type D6Q-RD-CAP (ITC) (supplier: Eurodis)
LC display, 1 line, 16 characters, type LM161556 (Sharp) (no backlight) or type M16417DY (Seiko) (with backlight) (supplier: Eurodis)
PCB, order code 980084-2

processor board it is probably easier to build up than the receiver board. The board is single-sided. The design is shown in **Figure 6**, and our finished prototype, in **Figure 7**.

Like the main receiver board, the control board is available ready-made from the Publishers. If you buy the complete project from a kit supplier, the PCBs and/or the programmed PIC may or may not be included, so do make sure you know what you get!

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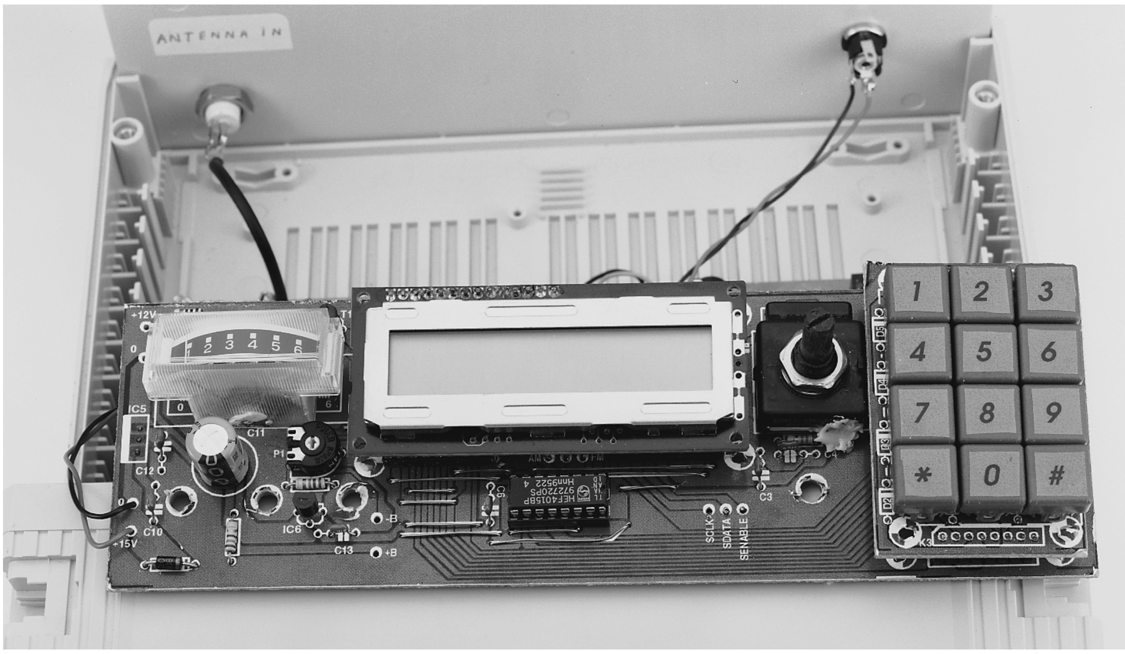

Figure 7. Built up control board.

The keypad section has to be cut from the main control board.

The main point to note about this board is that all components on it must be mounted at the lowest possible height to enable the board to be properly fitted against the inside of the front panel later. If necessary, components IC5 and C11 are mounted at the solder side of the board. For the rest, the control board is conventionally populated, i.e., you use IC sockets and simply follow the parts list and the component overlay. There are, however, a number of wire links which we recommend you fit first.

An important note we should make about building this board is that the switches, the LCD and the S-meter are mounted at such a height that the S meter is flush with the front panel, the LCD is just behind it, and the switches just protrude. This may sound complex, but it is in fact fairly easy to achieve by inserting the control board in the small vertical slots inside the case. These slots are specially made to hold vertically mounted boards., and govern the mounting height of the previously mentioned elements. In our prototype, the LCD was mounted on a SIL pin strip (K1) at about 12 mm above the control board surface. The keypad sub-board was mounted at a height of about 10 mm on two 8-way SIL pinheaders and mating sockets (K2 and K4). By ‘nudging’ the pinheaders in the sockets, the keytops can be made to protrude about 1 mm from the front panel.

The S meter sits in a square clearance cut in the controller board. Once its final position is known, it may be secured to the board with a few drops of glue.

WIRING

The wire connections between the main receiver board and the control board are made in short lengths of flatcable. A 6-way cable is used for the ‘preselector’ cable (Q0-Q5), and 3-way cables for the serial bus (SCLCK, SDATA and SENABLE) and the mode selection (FM, AM, SSB). Solder these cables at the receiver board first, and then find the corresponding points on the control board. **Connect the wires at the solder side of the control board.** This is not necessary for the LCD backlight connections, if used.

The controller board has the 12-V voltage regulator on it, so it is connected to the mains adaptor output. The regulated 12-V supply voltage is connected to the receiver board. A mains adaptor with a current rating of 12 V at about 1 A will be fine for the receiver. Note that although an input voltage of 15 V is required, most mains adaptors actually supply at least 15 V when set to 12 V.

The S meter is directly connected to the receiver board (wires to S+ and ground). If the meter has internal lighting, then run two wires from the lamp connections to the terminals +M and –M on the control board. The same for the LCD backlight (if available), which is connected to terminals +B and –B, also on the control board.

A loudspeaker may be mounted inside the case, or a socket may be fitted on the rear panel for connecting an external loudspeaker (often to be preferred).

FRONT PANEL

The layout of the front panel is shown in **Figure 8**. As always you can use this drawing as a template and a master for transferring onto a transparency.

The layout also provides the size of all holes and rectangular clearances to be cut. Unfortunately, a ready-made front panel foil is not available from the Publishers.

The rear panel only holds the RF input socket (a BNC or SO239 type), an external loudspeaker (or headphones) socket and the mains adaptor socket.

ADJUSTMENT

The receiver is designed such that it should be able to receive strong stations with all trimmers and inductor cores set to mid-travel.

To be able to adjust the receiver, you have to have the two PCBs temporarily connected to each other. Likewise, a power supply, and antenna and a loudspeaker are provisionally connected up. Turn the volume control way down.

Once you have ascertained the level and the polarity of the 15-V DC supply voltage, connect it to the control board and switch on.

Start by adjusting the LCD contrast using P1. Typically this preset has to be turned almost fully ccw.

The first time you switch on the receiver, memory 0 will contain data that makes no sense and, worse, makes manual tuning impossible. So, first program memory 0 with meaningful information (see below under Operation).

Initially, we recommend tuning to a strong medium-wave (MW) band broadcast station, say BBC Radio 1. Type the frequency into the display, confirm with #, and adjust the 1-MHz reference oscillator (C81) for highest S meter indication. Next, carefully adjust the cores in L14 and L18 for best reception, **using a plastic trimmer tool** (if you don’t have this, file down a plastic egg spoon or a matchstick for ovens).

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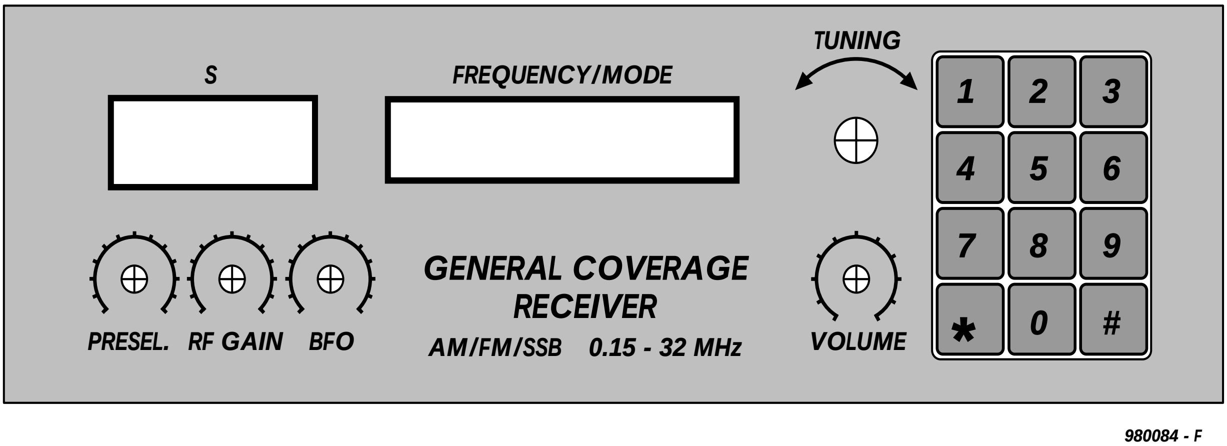

Figure 8. Front panel layout shown at 75% of true size.

If the signal gets very strong, change to a foreign broadcast or a national one which you know you can only receive marginally. Now peak the other two trimmers, C21 and C42, for the highest S meter reading, if necessary reducing the RF gain. The remaining inductor in the receiver, L19, is adjusted for best audio quality of an FM CB station in the 27-MHz band. Failing an off-air FM signal you can also adjust it for minimum audio output when receiving an AM station.

OPERATION

The program developed by the author and burnt into the PIC microcontroller (Publisher's order code 986517-1) provides easy operation of the receiver by driving the LCD and scanning the keyboard. The keyboard allows you to enter the frequency you want, as well as the associated bandwidth (3 or 12 kHz) and mode (AM, FM or SSB). The LCD presents the following readout:

mmmb p fffff kHz

where

mm(m) =	AM/FM/SSB	(receiver mode)
b =	n/w	narrow or wide bandwidth
p =	1 – 6	preselector band
fffff =	150 – 32000	receive frequency in kHz

The keyboard functions are as follows:

fffff#	enter frequency in kHz
01	select AM mode
02	select SSB mode
03	select FM mode
04	select narrow-bandwidth (3 kHz)
05	select wide bandwidth (12 kHz)
00	LCD backlight on/off (if available)
***mm#**	store frequency at memory location mm
#mm#	load frequency from memory location mm

where

mm = 00 – 20; defaults to 00 when the receiver is switched on

fffff = 150 – 32000 (kHz)

PRACTICAL RESULTS

Obviously this receiver can not be expected to perform like the latest £1k+ JRC communications receiver. Overall performance is quite good, however, provided you give some thought to the antenna. Even with a simple telescopic antenna, stations at distances of hundreds of miles could be received. The amount of digital interference caused by the microcontroller was found to be so low as to present no problems at all. No wonder, the PIC is asleep most of the time!

Radio amateurs in the 20, 40 and 80-metres bands usually employ SSB for voice communication. With the BFO control on the receiver set to about mid-travel a BFO frequency of about 455 kHz is obtained. Turning it clockwise and anti-clockwise over about 90 degrees then provides the right setting for USB and LSB respectively. Because of the widespread use of synthesizer-controlled transceivers, many hams use a 1-kHz raster. Even if this is not the case, reception is possible by turning the BFO so that a frequency shift of about 500 Hz is obtained.

Because most radio amateurs use relatively low power levels (as compared to broadcast stations), it pays to use a relatively long wire antenna. The author found that a wire with a length of about 5 m, hung between two houses, gave reasonable results already.

The prototype of the receiver was also successfully tested with the superb Omega-2 and Omega-3 magnetic loop antennas described in the September 1998 issue of *Elektor Electronics*.

Finally, the author welcomes any feedback you may want to provide on building and using the general-coverage receiver described here. His email address is G.Baarst@hot.a2000.nl

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